Single-Phase full converter with RL Load –

The operation of converter shown in fig 3(a) can be devided into two identical modes: Mode 1 when T_1 ad T_2 conduct, and mode 2 when T_3 ad T_4 conduct. The output current during these modes are similar and we need to consider only one mode to find the output current i_L.

Mode 1 is valid for $\alpha \leq \omega t \leq (\pi + \alpha)$. If $v_s = V_m \sin \omega t$ or $v_s = \sqrt{2} V_s \sin \omega t$ is the input voltage, the load current i_L during mode 1 can be found from

$$L \frac{di_L}{dt} + R i_L + E = \sqrt{2} V_s \sin \omega t \quad \text{for } i_L \geq 0$$

Solution of this equation

$$i_L = \frac{\sqrt{2} V_s}{Z} \sin(\omega t - \theta) + A_1 e^{-(R/L)t} - \frac{E}{R} \quad \text{for } i_L \geq 0$$

where load impedance $Z = [R^2 + (\omega L)^2]^{1/2}$ and load angle $\theta = \tan^{-1} \frac{\omega L}{R}$.

Constant A_1 can be determined from initial condition: at $\omega t = \alpha$, $i_L = I_{L0}$ is found as

$$A_1 = \left[I_{L0} + \frac{E}{R} - \frac{\sqrt{2} V_s}{Z} \sin(\alpha - \theta) \right] e^{(R/L)(\alpha/\omega)}$$

Substituting A_1 into gives

$$i_L = \frac{\sqrt{2}V_s}{Z}\sin(\omega t-\theta) - \frac{E}{R} + \left[I_{L0} + \frac{E}{R} - \frac{\sqrt{2}V_s}{Z}\sin(\alpha-\theta)\right]e^{(R/L)\left(\frac{\alpha}{\omega}-t\right)} \quad -(21)$$

At the end of mode-1 in the steady state condition $i_L(\omega t = \pi+\alpha) = I_{L_1} = I_{L0}$. Applying this condition we get

$$I_{L0} = I_{L_1} = \frac{\sqrt{2}V_s}{Z}\,\frac{-\sin(\alpha-\theta) - \sin(\alpha-\theta)e^{-\left(\frac{R}{L}\right)\left(\frac{\pi}{\omega}\right)}}{1-e^{-(R/L)(\pi/\omega)}} - \frac{E}{R} \quad -(22)$$

for $i_{L0} \geq 0$

The critical value of α when I_{L0} becomes zero can be solved for known value of θ, R, L, E and V_s by an iterative method.

rms value of a thyristor can be found from eq. (21)

$$I_R = \left[\frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} i_L^2\, d(\omega t)\right]^{1/2}$$

r.m.s. output current can be found as

$$I_{rms} = \left(I_R^2 + I_R^2\right)^{1/2} = \sqrt{2}R$$

Average current of thyristor can be found as

$$I_A = \frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} i_L\, d(\omega t)$$

Average output current can be determined as

$$I_{dc} = I_A + I_A = 2I_A$$

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-t) Discontinuous mode (Load current) — The critical value α_c at which I_{L0} becomes zero can be solved. Deviding eq. (22) by $\frac{\sqrt{2}V_s}{Z}$, and substituting $R/Z = \cos\theta$ and $\frac{\omega L}{R} = \tan\theta$, we get

$$0 = \frac{\sqrt{2}V_s}{Z}\sin(\alpha-\theta)\left[\frac{1+e^{-(R/L)(\pi/\omega)}}{1-e^{-(R/L)(\pi/\omega)}}\right] + E/R$$

which can be solved for critical value of α

$$\alpha_c = \theta - \sin^{-1}\left[\frac{1-e^{-\left(\frac{\pi}{\tan\theta}\right)}}{1+e^{-\pi/\tan\theta}}\cdot\frac{x}{\cos\theta}\right]$$

where $x = \frac{E}{\sqrt{2}V_s}$, is the voltage ratio and θ is the load impedance angle. for $\alpha > \alpha_c$, $I_{L0} = 0$. The load current described by eq. (21) flows only during the period $\alpha \leq \omega t \leq \beta$. At $\omega t = \beta$, the load current falls to zero again.

Note: • Varying α from 0 to π can vary the average output voltage from $\frac{2V_m}{\pi}$ to $-\frac{2V_m}{\pi}$, provided that the load is highly inductive and load current is continuous.

- for a purely resistive load, α is varies from 0 to $\pi/2$ and the average output voltage vary from $\frac{2V_m}{\pi}$ to 0.

- The full converter can operate in two quadrant for highly inductive load and operate in one quadrant for a purely resistive load.